REMARKS

Claims 1-20 are pending in the application. Claims 1-20 stand rejected. Claims 21-50 are withdrawn from consideration. The present Amendment cancels claims 21-50. In light of the following argument, Applicants earnestly solicit favorable reconsideration.

Applicants include in this response 3 references and one figure, all discussed below. In light of the Examiner's position, these references are included to aid in the explanation of the differences between the claimed invention and the cited art.

On the Merits

Claim Rejections - 35 U.S.C. §102

Claims 1-20 were rejected under 35 U.S.C. §102(b) as being anticipated by *Inomata* (EP 1 085 586). Favorable reconsideration is earnestly solicited.

The Examiner argues that paragraphs 47 and 58 of *Inomata* teach "a first magnetic layer and a second magnetic layer having different magnitudes of magnetization" and that *Inomata* discloses that the layer may be of different thicknesses, which creates a different magnitude of the magnetic layer in accordance with the instant specification." However, the Examiner is incorrect for the reasons discussed below.

EP '586, a patent by one of the inventors of the present application, is a patent regarding a double tunneling junction. It is mentioned partly to utilize an anti-parallel bond triple layer film as a ferromagnetic layer (Claim 3 of EP '586).

The present specification discusses on page 2 to use an anti-parallel bond (SyAF) triple layer film itself as a tunneling junction device. This is made in reference to one of the present

inventor's previous applications (Koichiro Inomata's patent application (Japanese Patent Laid Open Application No. H09-251621 A, filed on March 18, 1996)

The present invention proposes SyAF as a spin injection magnetization reverse device with the premise that it is already known. There had not been the concept of a spin injection magnetization reversal before Inomata in 1996, and hence Inomata recites with the premise of magnetization reversal by the external magnetic field induced from electric current in another wiring outside the device.

As shown in Fig. 1 of Inomata '621 (attached hereto), a magneto-resistance element comprises a magnetic laminated film 6, a tunnel insulator film 5, and a ferromagnetic conductive film 4. The magnetic laminated film 6 comprises a first ferromagnetic conductive layer 1, a nonmagnetic conductive layer 3, and a second ferromagnetic conductive layer 2. Fig. 2 of Inomata '621 shows mutual reversal of magnetization of the first ferromagnetic conductive layer 1 and the second ferromagnetic conductive layer 2.

The magnetic laminated film 6 disclosed in Inomata may correspond to SyAF of the present invention.

Spin injection magnetization reversal is to give spin torque to a ferromagnetic free layer by conducting spin polarized current in the ferromagnetic free layer, and to reverse its magnetization.

Explanation is first made of spin injection magnetization reversal of a giant magnetoresistance (GMR) device. The GMR device has a three-layered structure with a fixed ferromagnetic layer (also called pinned), a paramagnetic (non-magnetic conductive) layer and a

ferromagnetic layer as a free layer. Conventionally, the magnetization of a ferromagnetic layer as a free layer is reversed by an external magnetic field.

Spin injection magnetization reversal reverses the magnetization direction of the ferromagnetic layer as a free layer of GMR device only by electric current flowing the device without applying external magnetic field. The spin injection magnetization reversal of a GMR device was predicted in a paper written by J. C. Slonczewski, J. Magn. Magn. Mater. 159 L1 (1996), Abstract.

This paper is mentioned in the present application in paragraph [0007], and has already been submitted in an IDS.

In Slonczewski's paper, a GMR device has a structure comprising of a ferromagnetic layer F1, a paramagnetic layer B, and a ferromagnetic layer F2 (See Slonczewski's paper, p. L2 Left-side section, lines 25 - 34, Fig. 1). Here, the paramagnetic layers A and C connected to the ferromagnetic layer F1 and the ferromagnetic layer F2 are the layers to be electrodes.

The current density (j) required for spin injection magnetization reversal is estimated by calculation as 10^7 Acm^{-2} (See Slonczewski's paper, p. L6 Right-side section, line 3 from the bottom - p. L7 Left-side section, line 3).

Experimental results and their theoretical calculation of magnetization reversal of a ferromagnetic layer to be a free layer of a GMR device only by electric current without applying an external magnetic field as shown by J. Grollier et al., Physical Review B, 67, 174402, (2003).

A resistance of a CPP (current perpendicular to the plane) type GMR device consisting of a first ferromagnetic layer (Co), a paramagnetic layer (Cu), and a second ferromagnetic layer (Co), is explained in Figs. 1 and 2. It is described that magnetic reversal occurs with positive and negative current in the state without external magnetic field application ($H_{appl} = 0$) (Grollier, p. 174402 - 1, II).

In Fig. 1 of Grollier, magnetizations have the same direction for P (parallel) of the first and the second ferromagnetic layers, and resistance is lowered. Magnetizations differ from one another for AP (anti-parallel) of the first and the second ferromagnetic layers, and resistance is higher.

The current required for spin injection magnetization reversal is estimated in a case without application of external magnetic field ($H_{appl} = 0$) from Fig. 1, and the current density is calculated from the current. The current densities are shown where $j^{P \to AP}$ is about - 1.25 x $10^7 A/cm^2$, and $j^{AP \to P}$ is about + 1.17 x $10^7 A/cm^2$ (See Grollier, p. 174402 - 2,lLeft-side section, lines 2 - 5 from the bottom.).

The current required for spin injection magnetization reversal of a GMR device is expressed by Equation (1) below, and the current density by Equation (2) below.

$$I_c^{\pm} = \alpha e M_s V\left[H_{ext} \pm \left(H_{ani} + 2\pi M_s\right)\right] / \hbar \cdot g(\theta) \qquad (1)$$

Equation (1) divided by a device area gives the following Equation (2) regarding current density.

$$J_c^{\pm} = \alpha e M_s t\left[H_{ext} \pm \left(H_{ani} + 2\pi M_s\right)\right] / \hbar \cdot g(\theta) \qquad (2)$$

Here, ± is current direction, α a damping factor, e a unit charge of an electron, Ms a saturation magnetization of a ferromagnetic free layer, V a volume of the device, H_{ext} an external magnetic field, 2πMs a demagnetization field in the direction perpendicular to a film surface, t a thickness of ferromagnetic free layer whose magnetization direction is reversed by an external magnetic field or by electric current, that is, the film thickness of a ferromagnetic free layer, and $g(\theta)$ is a g-factor.

From this, a critical current required for magnetization reversal of a GMR device without applying an external magnetic field ($H_{ext} = 0$), but with conducted current is proportional to a device volume, and the more decreasing in the device size, the lower the current required for magnetization reversal. That is, the thinner the thickness t of a ferromagnetic free layer, the lower the current density required for spin injection magnetization reversal.

This is the reverse relationship to magnetization reversal by the magnetic field (electric current induced magnetic field) generated by the external current to a GMR device and by this magnetic field. Please see Fig. 1 attached herewith.

As is shown in Fig. 1, the write-in current is decreased if a device size is made small, when a GMR device is spin injection magnetization reversed.

Here, the Equation (2) above is derived by substituting Equation (3) of Grollier, Hd = 4πMs, $H_{ext} = H_{appl}$, and else to Equations (8) and (9) of Grollier.

A TMR device is a device consisting of a ferromagnetic layer as a fixed layer, an insulation layer, and a ferromagnetic layer as a free layer. The insulation layer is formed with a thin film so that a spin electron is conducted by tunnel injection. The TMR device has a

structure wherein a paramagnetic layer such as Cu of the GMR device is substituted with a tunnel insulation layer such as aluminum oxide.

For the TMR device, the current density is given by Equations (3) and (4) below. These Equations are shown in Z. Diao et al., Appl. Phys. Lett., 87, 232502 (2005).

Diao, p.232502 - 2, right-side section equation (1) and line 4 shows the following Equation (3).

$$J_{c0} = \frac{2e\alpha M_s t\left(H + H_K + 2\pi M_s\right)}{\hbar\eta}, \tag{3}$$

where $$\eta = \frac{P/2}{1 + P^2 \cos\theta}$$

Here, α is a damping factor, t and M_s respectively a film thickness and magnetization of a ferromagnetic free layer, H and H_k respectively an external and an anisotropy magnetic fields, η spin transfer efficiency, and P is spin polarizability.

It is seen from Equation (3) that to lower the critical current density Jc0 becomes larger P and α, t, and M_s must become smaller.

That is, the thinner the thickness t of a ferromagnetic free layer, the lower the current density required for spin injection magnetization reversal.

This means that using SyAF of a triple layer structure makes film thickness thicker, and the current density higher, resulting in a disadvantage.

Therefore, it would not have been obvious from '586 to use SyAF as a spin injection magnetization reversal device.

The present inventors consider that if SyAF particularly using Ru is used, then the above-mentioned η increases by spin filter effect of Ru (described in the present application paragraph [0054], as Ru is a material easily transmitting minority spins), bringing about lowering of current density as a result. Such lowering of spin injection magnetization reversal current is found by the present invention, and this is not obvious from '586.

Claims 6 and 13 (Aspect ratio):

The Examiner asserts that Fig. 36 of '586 discloses the aspect ratio (T1/W and T2/W) of the first and the second magnetic layers of SyAF is 2 or lower (See '586, paragraph [0194]). Applicants respectfully disagree.

Fig. 36 of '586 is a double tunnel junction device of Fig. 1, and SyAF layer is not included. T1 and T2 are sample names of Example 7 (See '586, paragraph [0186].) and T1 and T2 do not mean thickness of any layers in '586 at all.

Fig. 36 is also a figure illustrating the relationship between the reciprocal number of a junction width and a reverse magnetic field of a free layer. Paragraph [0194] of '586 does not disclose anything relating to an aspect ratio.

Therefore, Applicants respectfully submit that the limitation of aspect ratio is conducted by the claimed invention, and it is not obvious from '586.

Claim 15:

Independent claim 15 requires in part:

a ferromagnetic free layer provided in contact with said spin injection part....

The Examiner contends this feature is shown in figure 10, by reference numeral 105. In the response presented to the Patent Office on June 1, 2007, Applicants argued that layer 105(a) of figure 10 appears to be the only layer in contact with the "spin injection part." Furthermore, layer 105(a) is a "first ferromagnetic layer." Claim 15 specifically requires a "ferromagnetic free layer" in contact with said spin injection part.

The Examiner maintains his position regarding this feature, however Applicants respectfully submit that the Examiner's position is untenable. The Examiner considers reference numeral 105, which includes layers 105(a), 105(b) and 105(c), is in contact with the spin injection part 104. That is, layer 105 is a ferromagnetic free layer according to the Examiner.

According to the Examiner's own interpretation, layer 105(a) contains ferromagnetic material. Thus, if the Examiner considers layer 105 to be a complete layer in and of itself, it is not ferromagnetically free. If the Examiner considers layer 105 to be 3 layers (105(a), 105(b) and 105(c)), then a ferromagnetic layer 105(a) is in contact with the spin injection part. The Examiner may not interpret the reference two different ways to suit his own purposes, the interpretation must remain consistent.

As such, Applicants respectfully submit that the Examiner's rejection is inappropriate should be withdrawn.

Furthermore, a device cited in Claim 15 has a structure wherein SyAF layer of Claim 1 is substituted with a ferromagnetic free layer 27 and a nonmagnetic layer 28 (See Fig. 4 of the present invention.). This structure is not disclosed in '586.

The function of the device cited in Claim 15 is to spin injection magnetization reverse the direction of the electron injected from a spin polarization part 9 and an injection junction part 7, like the spin injection device of Fig. 1 of the present invention, that is, by the direction of electric current.

(1) Function of Nonmagnetic Layer 28:

The nonmagnetic layer 28 is provided so as to transmit minority spins and to reflect majority spins at the interface of a ferromagnetic layer 27 (See paragraph [0054]). That is, the nonmagnetic layer 28 has a spin filter effect to transmit minority spins.

(2) See paragraph [0056] for functional mechanism of spin injection magnetization reversal.

Applicants submit that the invention recited in Claim 15 is done by the present invention, and neither its structure nor function is obvious from '586.

<u>Claim 17:</u>

As claim 17 requires similar features to those discussed above in claim 15, specifically, "a ferromagnetic free layer provided in contact with said spin injection part," the same argument also applies to claim 17.

Furthermore, a difference of the device cited in Claim 17 to the device in claim 15 is the point that the a ferromagnetic fixed layer 29 is provided onto the surface a nonmagnetic layer 28 of the device disclosed in Claim 15.

This device structure is also not disclosed in '586.

The function of the device cited in Claim 17 is to spin injection magnetization reverse the direction of the electron injected from a spin polarization part 9 and an injection junction part 7,

like the spin injection device of Fig. 1 of the present invention, that is, by the direction of electric current. However, the device recited in Claim 17 does not have the SyAF as disclosed in Claim 1 device.

In the device claimed in 17, only a ferromagnetic free layer 27 among a ferromagnetic free layer 27, nonmagnetic layer 28 and a ferromagnetic fixed layer 29 changes its magnetizaition direction with the spin injection magnetization reversal.

In SyAF of Claim 1, when the first ferromagnetic layer 4 changes its magnetizaition direction with the spin injection magnetization reversal, then the magnetizaition direction of the second ferromagnetic layer 5 changes at the same time.

The roll of the nonmagnetic layer 28 is the same as explained in Claim 15. That is the nonmagnetic layer 28 acts as a spin filter to transmit minority spins and to reflect majority spins at the interface.

See paragraphs [0058] to [0062] and Fig. 7 for functional mechanism of spin injection magnetization reversal.

The invention recited in Claim 17 is done by the present invention, and neither its structure nor function is obvious from '586.

Conclusion

In view of the aforementioned remarks, Applicants submit that that the claims, as herein amended, are in condition for allowance. Applicants request such action at an early date.

If the Examiner believes that this application is not now in condition for allowance, the Examiner is requested to contact Applicants' undersigned attorney to arrange for an interview to expedite the disposition of this case.

If this paper is not timely filed, Applicants respectfully petition for an appropriate extension of time. The fees for such an extension or any other fees that may be due with respect to this paper may be charged to Deposit Account No. 50-2866.

Respectfully submitted,

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Attachments: Illustrated Drawing
JP 09-251621, (Inomata)
Field dependence of magnetization reversal by spin transfer, (Grollier)
Spin transfer switching and spin polarization in magnetic tunnel junctions with MgO and Alo_x barriers, (Diao)